PCI / PCI EXPRESS Error Recovery White Paper

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Executive Summary

In the context of software applications, Reliability, Availability, and Serviceability (RAS) mean failures in the underlying processes and hardware components must not cause any interruptions in the overall system operation. Service transactions are adversely impacted during system failure and performance is affected because of the service down time in the failed system. Recovering from the failure early, managing the remaining working components of the system, or both, with minimal impact to the business services, is the key for an optimized system that meets the RAS criteria.

In computer systems, PCI™ failures constitute a significant percentage of errors. The PCI Error Recovery (PCI ER) feature enables the detection of PCI bus parity errors, isolation of the failed I/O path, and recovery of cards from errors. Enabling the PCI ER feature avoids system crash, decreases system downtime, and supports single system high availability.

On HP-UX 11i v2 OS legacy systems, user intervention is required to attempt recovery from PCI errors. The *olrad* (1 M) command and the Attention Button can be used to recover and restore the slot, card, and driver to a usable state, without taking the system down. Whereas, HP-UX 11i v3 has the ability to automatically recover from PCI errors and restore the slot/driver without user intervention.

Problem Statement

Without PCI/PCI EXPRESS® (PCIe®) error recovery, I/O paths operate in Hardfail mode. While operating in this mode, a PCI I/O error/a rope error / PCIe errors, causes an MCA on a PIO read and brings the system down. Using the PCI ER feature, PCI I/O paths can be set to SoftFail mode if the platform and all the adapter drivers support this feature.

Historical Evolution of PCI/PCI-Express Error Recovery (ER)

On systems running HP-UX 11i v1, the PCI bus errors are handled and the cards are recovered manually. This feature was shipped as a site specific patch.
On systems running HP-UX 11i v2, the PCI bus errors are handled and the cards are recovered manually. The product was shipped as an optional product bundle (*PCIErrorHandling)* on the SupportPack media starting with AR0806 release.
On systems running HP-UX 11i v3, the PCI bus errors are handled and the cards are recovered automatically. This feature is part of the Base Operating Environment.

Why PCI/PCI-Express Error Recovery

Interruptions in online transaction processing system and enterprise resource planning service caused from a failed application or system or hardware component, can be costly and disruptive. The impact of service downtime continues to grow as companies move toward a real-time business model. Moreover, as companies become more connected and response times shorten, the cost of service downtime continues to increase. For these reasons, businesses invest large amounts of money in maintaining the RAS of servers in the IT infrastructure. The PCI ER feature can enable a drastic reduction in downtime of the system caused by PCI errors.

Figure 1 and Figure 2 compares the system behavior, when a PCI error occurs, with and without error recovery feature.

Figure 1: Without PCI Error Recovery

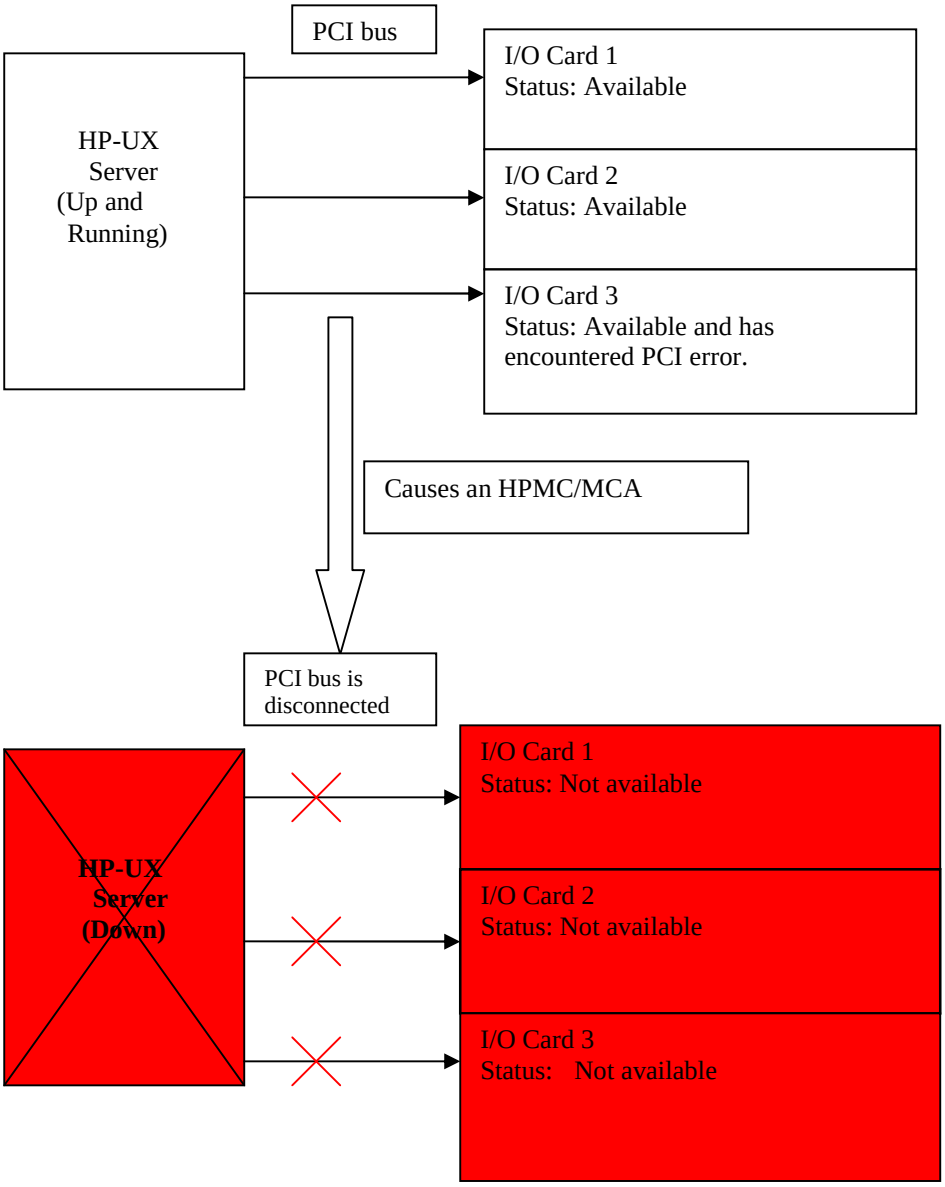
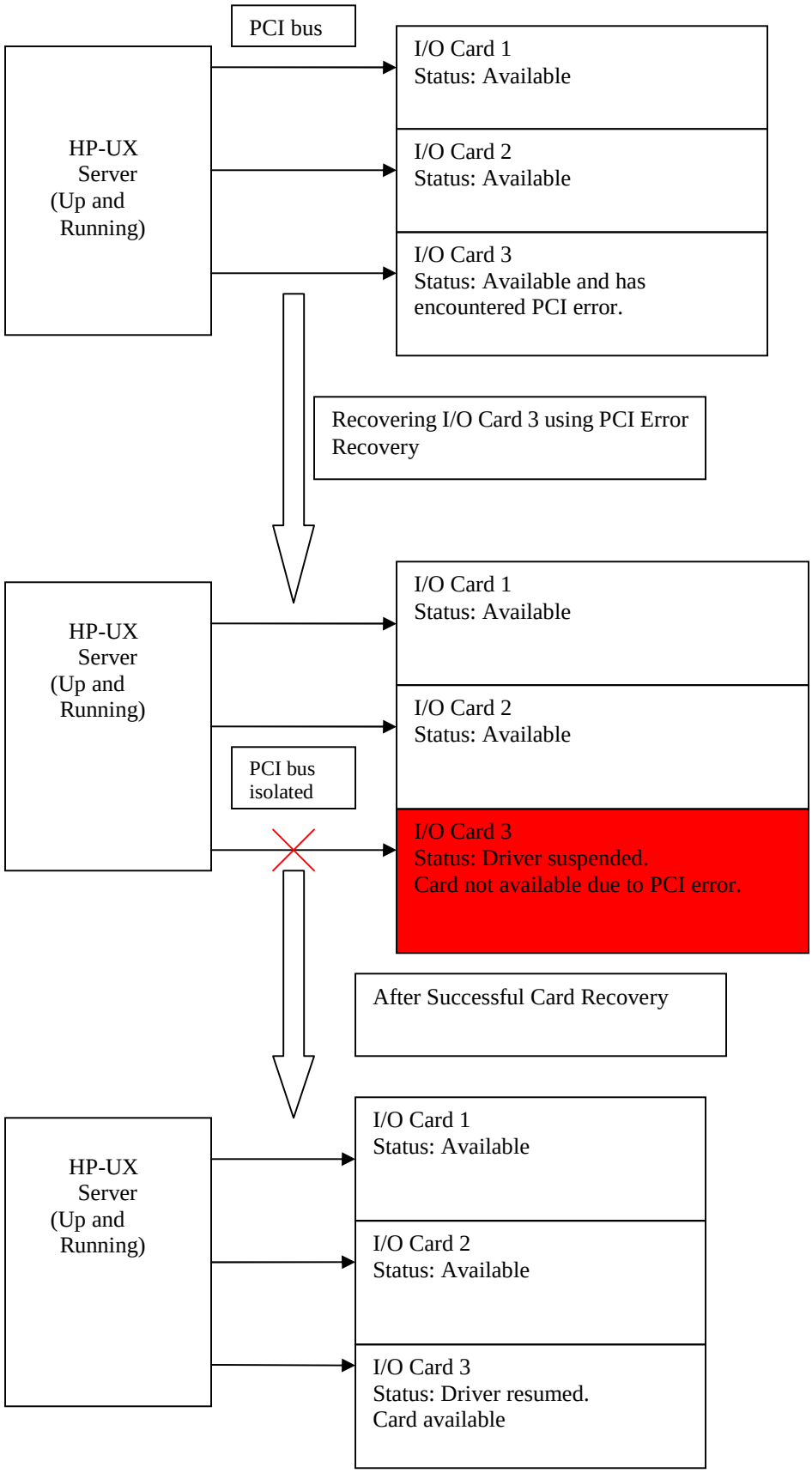


Figure 2: With PCI Error Recovery



PCI ER decreases the frequency of crashes, service calls, & repair rates for PCI errors by a factor of 20 to 25 times. Without PCI error recovery, the entry-level system I/O errors account for more than 20% of all errors in the system.

Tables below list the time taken by the PCI/PCIe cards to recover from PCI errors with the error recovery feature.

Table 1: PCI / PCIe Card Recovery with PCI Error Recovery Feature on Legacy Platform

Event	Time Taken
PCI / PCIx slot card recovery	In the range: 10 secs – 2.5 mins
PCIe card recovery	~ 6 secs

Table 2: PCIe Card Recovery with PCI Error Recovery Feature on HP Superdome 2 Platform

Event	Time Taken
PCIe card recovery	~ 5 secs

Refer to concurrent dump whitepaper (link provided below) for details on time taken for the system to recover from MCA due to PCI I/O errors, without error recovery functionality.

http://www.hp.com/go/hpux-core-docs under HP-UX 11i v3 category.

Types of Error Recovery

The PCI/PCIe cards can be recovered from the errors either manually or automatically.

Manual recovery, also known as Error Handling, is supported on HP-UX 11i v2 OS on legacy platforms only. In this type of error recovery, the PCI / PCIe cards are isolated due to errors and must be manually recovered. Users can use olrad (1 M) command or Attention Button to recover the cards manually.

Automatic recovery, also known as Error Recovery, is supported on HP-UX 11i v3 OS. In this type of error recovery, the PCI / PCIe cards that are isolated because of errors are automatically recovered by the core PSM (Platform Support Module).

Table 3 provides the error recovery OS support details.

Table 3: Error Recovery OS Support Details

Types of Error Recovery	OS Support
Manual error recovery	On HP-UX 11i v1 and HP-UX 11i v2 OS legacy platforms, users are required to manually recover* cards from PCI errors. Non hot-pluggable slots are not supported on HP-UX 11i v1 and HP-UX 11i v2 systems.

Automatic error recovery	On an HP-UX 11i v3 system, PCI errors are recovered automatically. If automatic recovery fails, users can attempt to manually recover* cards on hot-pluggable slots but cannot manually recover cards on non hot-pluggable slots.

Note: The PCI Error recovery feature is neither supported on shared/switched hot-pluggable slots on HP-UX 11i v1, HP-UX 11i v2, and HP-UX 11i v3 Operating Environments, nor on Core IO on HP Superdome 2 platform.

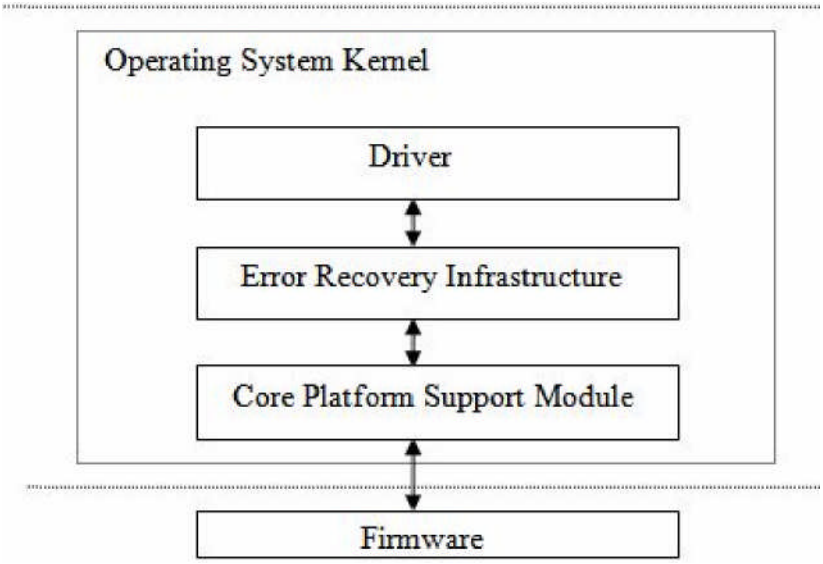
*Manual recovery may also fail if there is persistent error condition.

How PCI / PCI-Express Error Recovery Works

When an I/O driver detects PCI bus parity errors, it reports the errors to Error Recovery Infrastructure and then to the core platform support module.
Core PSM implements error recovery functionality using interfaces that are independent of the platform. This module verifies if the error is a device error or a bus error. If the error is a device error then the PSM ignores the error. Otherwise, the PSM module handles the I/O error and notifies the error recovery infrastructure about error handling. While handling the error, the core PSM invokes firmware interface (like Health checker daemon as shown in the figure below) which logs and clears the error.

Figure 3 depicts the PCI I/O error recovery control flow.

Figure 3: PCI Error Recovery Flow Diagram



The PCI I/O errors are handled as follows by the system that supports error recovery functionality:

- Determine whether the platform and the drivers are error recovery capable. If that is the case, set the I/O paths to SoftFail mode.
- When a driver detects an error, it reports the error to error recovery Infrastructure. The report is sent to the core PSM.
- To handle and recover from PCI error, the core PSM completes the following three phases:
    - Diagnose Phase
    - Synchronization (suspension) Phase and
    - Release (resumption) Phase

Diagnose Phase: During this phase, the I/O node information is passed from the driver to the core PSM. This node forms the initial root of the error path. The primary goal of this state is to gather additional information and determine the actual root of the error path. On PA-RISC platform system, during this phase the errors are logged in the firmware in SAL format on legacy platforms and UEFI format on HP Integrity Superdome platform.

No attempt is made during this state to recover the path from the error, and some hardware may be inaccessible.

Synchronization (suspension) Phase: During this phase, the core PSM attempts to clear logged errors

and suspend the I/O modules in the error path. When this phase is completed, it is assumed that drivers have suspended all activities for the devices in the error path. On HP Superdome 2 platform system, during this phase the Health Checker Daemon is invoked to log and clear the errors.

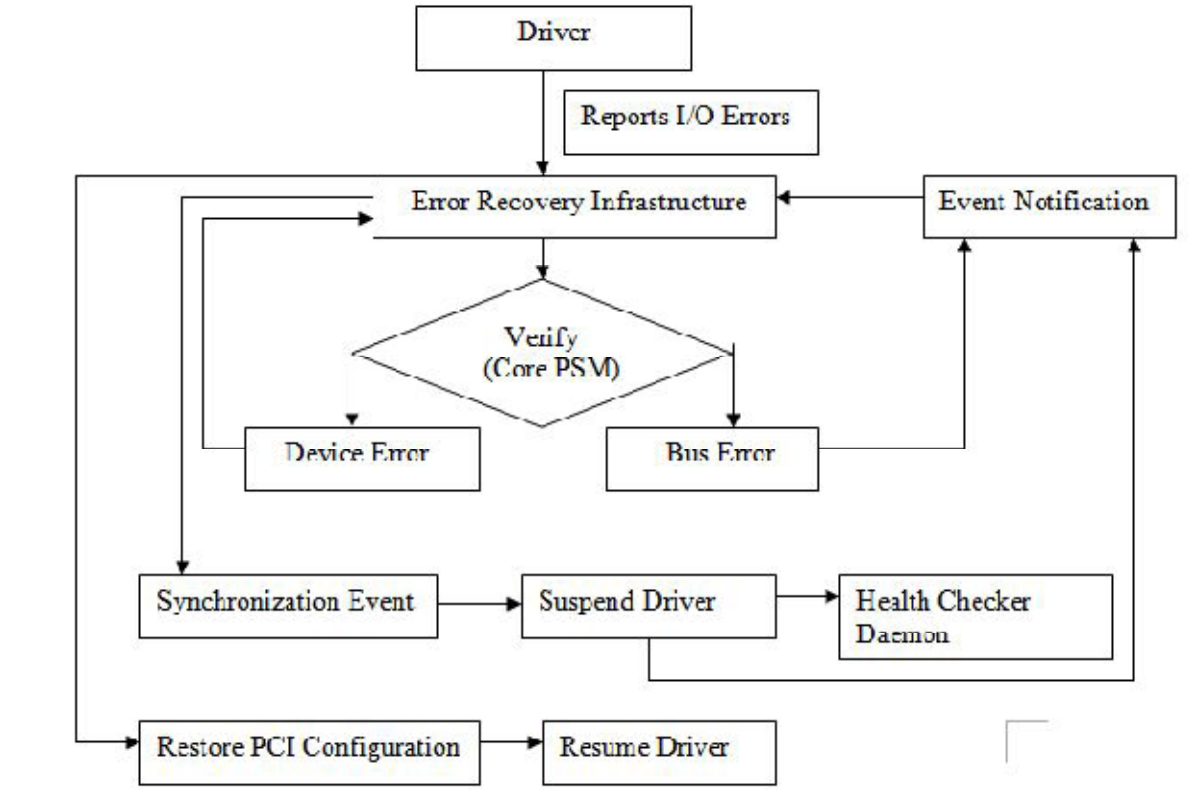
Release Phase: During this phase, the suspended I/O path is restored. It involves resuming the driver. If any I/O cards were left in a suspended state, the card will be replaced via a PCI OLR action.

For more information about PCI OLR, see *Interface Card OL* Support Guide*, posted at the following location:
http://www.hp.com/go/hpux-networking-docs under

HP-UX 11i v3 Networking Software category.

The following diagram depicts various phases of core PSM.

Figure 4: PCI Error Recovery Phases



Diagnostics decodes the error logs and saves the error information in /var/opt/resmon/log/event.log file.

Note: Only the PCI bus parity errors are handled by the error recovery feature. Device errors are not handled by this feature.

To summarize, when an error occurs on a PCI bus containing an I/O card, events occur in the following order:

- The I/O drivers are suspended
- The PCI bus is isolated from further I/O
- The error is logged and cleared
- The bus is reset
- The I/O drivers are resumed

Support of PCI/PCI-Express Error Handling and Error Recovery on HP-UX

PCI error handling and error recovery are supported only with some HP-UX version, I/O products and servers. For more information, see the support matrix available at the following location:

http://www.hp.com/go/hpux-networking-docs under HP-UX 11i v3 I/O Cards category.

There are several kernel tunables that can change the behavior of PCI error recovery operation. For more information about the kernel tunables, see *Tunable Kernel Parameters* section in the *PCI Error Recovery Product Note, 4th Edition, March 2010* document, posted at the following location:

http://www.hp.com/go/hpux-networking-docs under HP-UX 11i v3 I/O Cards category.

The above link provides information about PCI Error Recovery functionality, which is supported on HP-UX 11i v3 system.

For more information about the type of errors and corresponding events supported by the product on all platforms, see *PCI / PCIe Error Recovery Product Note* available at http://www.hp.com/go/hpux-networking-docs under HP-UX 11i v3 I/O Cards category.

Summary

The basic RAS features designed for HP Integrity and HP 9000 servers, when coupled with the PCI error handling and recovery mechanisms, enables high-end servers to meet the needs of a mission-critical environment. This is made possible by preventing customers from experiencing down-time as a result of system hang or unusable state of a system.

References

For more information about Error Handling functionality supported on HP-UX 11i v2 system, see *PCI Error Handling Product Note 3rd Edition,* at the following location:

http://www.hp.com/go/hpux-networking-docs under HP-UX 11i v2 I/O Cards

Glossary

Following is a list of terms used throughout this document:

Name	**Definition**
LBA	Local Bus Adapter
EBA	Express Bus Adapter
Machine Check Abort (MCA) / HPMC	Highest Priority interruption on Itanium® based systems (MCA) and on PA-RISC based systems (HPMC).
PIO	Programmable IO
PCI	Peripheral Component Interconnect
HardFail mode	The mode of operation of LBA, during which PCI errors cause an HPMC/MCA for fatal error during PIO read.

RC (Root Complex)	An entity that includes a host bridge and one or more root ports.
RP (Root Port)	A PCI Express port on a root complex that maps a portion of the tree structured PCI Express I/O interconnect through an associated virtual PCI bridge.
SoftFail mode	The mode of operation of LBA, during which PCI errors does not cause an HPMC/MCA for PCI I/O errors during PIO read. The LBA/EBA set in soft fail mode will be able to detect the Error appropriately, handle them, and then finally recover from the error.
Platform Support Module (PSM)	A module that implements routines to support some specific features for a functionality.
SPPA	Super Parallel Precision Architecture
Ropes	The PCI I/O protocol used to interconnect components in SPPA architecture

For more information

www.hp.com/go/hpux11i

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